Dislocation structures in creep-deformed nickel-based single crystal superalloys

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Single crystal nickel-based superalloys have been extensively used for gas turbine blades attributed to their exceptional creep resistance at high temperatures. This excellent mechanical property mainly benefits from the high volume fraction of coherently precipitated γ'-phase embedded in the thin channels of face-centered cubic γ-matrix, as the γ' phase shows anomalous yield behavior of increasing strength with temperature up to a critical temperature. The single crystal blades are casted in the [001] direction which shows the highest solidification rate and allows a reduction in the thermal stresses arising during operation. Creep resistance is one of the most important mechanical properties of superalloys because of the centrifugal forces and thermal stresses acting on the turbine blades.

The evolution of dislocation structures in both γ channel and γ' precipitates is known relating to the performance of alloys such as the creep rate and strain. The creep characteristics are generally believed being controlled by three interconnected microstructure processes: the increase of dislocation density in the γ channels which controls primary creep; pair wise cutting of two dislocations from γ channel into the γ' phase followed by their annihilation; and the coarsening of γ channels associated with rafting in later stages of creep. In this work, single crystal nickel-based superalloys are used to study the creep mechanisms at high temperatures with the combination of transmission electron microscopy and aberration-corrected scanning transmission electron microscopy. It is believed that the configurations of dislocations shearing in γ' precipitates play a key role in the dislocation movement, which has a substantial influence on the performance of alloys. At high temperatures, superdislocations were frequently observed. The cores of these superdislocations are composed of superpartial dislocations on two intersecting slip planes. The movement of the superdislocations relied on a combination of the glide and climb of two superpartials.

References:

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Acknowledgement

This work was supported by the National Natural Sciences Foundation of China (Grant Nos. 51390473, 51371177 and 11332010).